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ABSTRACT

Calculus has become the center of a heated debate within the mathematics community. There are those who question the very centrality of calculus in the mathematics curriculum. Evidence indicates that many current calculus courses are not serving students well. In addition, computers and advanced calculators can now do many of the manipulations that students learn in calculus. Discussed in this digest are: the status of calculus in high school mathematics; enrollment and success patterns in college calculus; the calculus needs of various college majors; calculus teaching methods in colleges and universities; and curriculum development support from the National Science Foundation. A list of 11 references is included. (CW)

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THE ROLE OF CALCULUS IN COLLEGE MATHEMATICS

Introduction - the calculus crisis?

Calculus has become the center of a heated debate within the mathematics community. There are those who question the very centrality of calculus in the mathematics curriculum. This perspective is clearly illustrated by the National Council of Teachers of Mathematics viewpoint that "The curriculum standards for grades 9-12 are built on the premise that calculus should no longer be viewed as the capstone experience of high school mathematics" (NCTM Draft, 1987, p 128). Likewise, Ronald G. Douglas points out that "Although calculus has formed the core of the undergraduate mathematics curriculum for most of this century there has been much debate recently concerning this role." (Douglas, 1987, p. 3).

Evidence indicates many of the current calculus courses are not serving students well. In addition, computers and advanced calculators can now do many of the manipulations that students learn in calculus.

What is the status of calculus in high school mathematics?

Approximately 300,000 students each year enroll in high school calculus classes. Advanced Placement (AP) Calculus Exams are currently taken by about 60,000 of these students each year . The number taking AP Calculus Exams has been increasing steadily since 1960.

Calculus has been the capstone course for high school mathematics. Recent work by the National Council for Teachers of Mathematics provides some suggestions for content to be included in secondary school mathematics related to calculus.

The draft of the National Council of Teachers of Mathematics' Curriculum and Evaluation Standards for School Mathematics (1987) states that, in grades 9-12, the mathematics curriculum should include the informal exploration of calculus concepts from both a graphical and numerical perspective so that all students can determine maximum and minimum points of a graph, interpret the results in problem situations and investigate the concepts of limit and area under a curve by examining infinite sequences and series. In addition, students intending to go to college should understand the conceptual foundations of limit, area under a curve, rate of change, slope of a tangent line and be able to analyze the graphs of polynomial, rational, radical, and transcendental functions (p. 128). Whether teachers in secondary schools will accept and therefore attempt to implement these suggestions remains to be seen.

In many ways the collegiate mathematics establishment has resisted the teaching of calculus by secondary teachers, relenting only when the Advanced Placement syllabus is used and students take the advanced placement examination. Whether or not this is a sound position, it is the case that many schools that teach calculus do not use the AP Syllabus, and many schools do not require students to take the examination.

The Second International Study suggests that many students who are enrolled in U.S. pre-calculus courses are actually exposed to many calculus concepts. It is, however, still the case that most U.S. students, even college preparatory students, do not take a calculus course in high school and those that do often pretend that they didn't and enroll in introductory calculus in college. What should the high school curriculum be? It will probably not be a full year calculus course for most students.

What are enrollment and success patterns in college calculus?

Participation and success in calculus are important issues. Calculus is among the top five collegiate courses in annual enrollment. Data indicate that in the academic year 1986-87 there were more than 300,000 enrollments in mainstream calculus 1 and just under 260,000 enrollments in non- mainstream calculus 1 (i.e., business calculus) in four-year colleges. Over 100,000 students were enrolled in calculus in two-year postsecondary institutions. In a technological society such large numbers are not surprising. Calculus is frequently considered to be a necessary prerequisite for many professions such as engineering, the natural sciences, and mathematically-related positions in business and higher education. Initial enrollment, however, does not guarantee success. Only 140,000 of the initial 300,000 students in the mainstream calculus sequence are likely to successfully complete their courses.

Two traditionally underrepresented groups in mathematics fare somewhat differently from one another. Hughes (1987) indicated that "There is considerable evidence, both anecdotal and statistical that women are doing well in calculus" (p 126). The situation for minority students seems much different. Malcolm and Treisman (1987) indicate that "Hundreds of capable minority students (are) felled by the calculus hurdle" (p 130). Newman and Poiani (1987) suggest that there is no difference in mathematical performance between minority and majority students if those students have comparable mathematical background.

Calculus is a critical filter in the science and engineering pipeline blocking access to careers for a large number of students. The calculus sequence must be modified so that more students will succeed.

What calculus do various college majors want?

Calculus includes among its traditional client groups engineering, physics, business, biological science and social science majors. Some people feel that the college calculus course which "tries to be all things to all people" is doomed. Recent conferences (Toward a Lean and Lively Calculus, 1986, and Calculus for a New Century, 1987)

give some indication that client disciplines are not happy with the calculus that students know. Most of the areas want students to have a conceptual understanding of the basic ideas in calculus rather than great computational and manipulative facility. Client populations seem very interested, in working with mathematics departments to revamp and refine calculus courses in order to better meet the needs of their majors. Emphasis on specific topics, more relevant applications related to their fields, more use of technology, and more effective instruction are among the requests most frequently cited.

How is calculus taught in colleges and universities?

While there is some agreement regarding the breadth and conceptual orientation of a desirable calculus course, there is evidence to suggest that the calculus that is actually taught is "the moral equivalent of long division." An examination of final examination questions in collegiate calculus courses (Steen, 1987) revealed that 90 percent of the items focused on calculation and only 10 percent on higher order challenges. Steen suggests that the curriculum of collegiate calculus has changed dramatically in the last two or three decades and that the change has not been a good one. He feels that the movement has been away from conceptual understanding about the nature of calculus and toward more "plug and crank" exercises, with undue emphasis on computation and manipulative skills. Whether or not one accepts this view, it is certainly the case that far too much time is spent in most calculus courses doing things that are best done by machines.

A study by Anderson and Loftsgaarden (1987) indicated several interesting features about college-level calculus instruction. Only 15 percent of the courses used computers. This is alarming because nearly all users of mathematics make extensive use of technology.

There is a feeling that in addition to the lack of integration of technology into calculus, much of the instruction is not effective. A variety of reasons are given for problems related to instruction. Some feel that the academic system which rewards research and not excellent teaching is partially to blame. Some believe a major part of the problem is due to heavy student loads for instructors and/or the use, in many cases, of unqualified instructors. Others believe the preparation of many students taking the courses is inadequate. Colleges and universities must find ways to provide instruction that is creative and thoughtful and that helps more students succeed in their studies.

Curriculum development support from the national science foundation (NSF)

The National Science Foundation (NSF) established a program to focus on the improvement of calculus at the collegiate level. The initial awards included five multi-year awards and nineteen planning grants.

Projects awarded are supporting a variety of strategies generally considered innovative and worthwhile. The intent of NSF is to provide leadership to major efforts and provide some support for exploratory type activities.

Summary

There seems to be at least some consensus (though by no means unanimity) in the profession that calculus will remain the principal point of entry to most mathematically based scientific careers. Content and instruction in calculus classes need dramatic improvement. Curriculum and instruction must take advantage of technology in ways that will improve student understanding of basic concepts and strengthen student ability to apply these concepts.

Many college client groups are not happy with the calculus preparation their students receive in mathematics departments. These groups want to work with mathematics departments to improve the calculus courses for their students.

The level of minority participation and success in college-level calculus is critically low. In order to guarantee full societal participation by minorities, their recruitment and retention in calculus programs must become a priority for the mathematics community. Recruitment of students will require strengthening the precollege mathematics of these students. Helping students complete college level calculus sequences will require both improving the precollege mathematics program and the calculus courses.

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